Summer performance of certified passive houses in Temperate Maritime Climates

PLEA 2017 EDINBURGH
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Abstract: The solar resource in Temperate Maritime Climates (TMC) can make a significant contribution to space heating demand given the relatively long space heating season, but is this at the cost of summer overheating? This paper reviews the recorded performance of the certified passive houses with contemporaneous houses built to the minimum building regulations in Northern Ireland. The metrics being gathered at five-minute intervals for the houses are analysed:

a. occupancy profile
b. indoor air temperature
c. indoor relative humidity
d. indoor carbon dioxide concentrations
e. outdoor temperature
f. outdoor relative humidity
g. wind speed
h. barometric pressure
i. energy consumption

In addition "soft" data was also gathered on the inhabitants' perception of indoor air quality, comfort levels, heating costs etc. for both the passive and non-passive houses.

Results & Conclusions. The key metrics are reported upon. In addition to the higher recorded temperatures of the passive houses, it is also seen that the average carbon dioxide concentrations are more uniform in the passive houses compared with the houses complying with the minimum building regulations. Further investigation is needed, however the possibility of high CO_2 readings due to insufficient ventilation (compared with the forced ventilation system of passive houses) is targeted for further investigation as part of the ongoing monitoring project.

Keywords: Passive House, Passivhaus, overheating, IEQ, IAQ

Introduction

As the prevalence of low-energy and near Zero Energy Buildings (nZEB) (e.g. Anon 2012) increases, focus is turning to the potential for summer overheating (e.g. PHI, 2014, McGill et al 2015, 2017) and means of controlling overheating (e.g. Colclough 2011). This paper presents an assessment of four of the seven NI (Northern Ireland) certified newbuild Passive Houses (PH) (PHI, 2017) in addition to five houses built to comply with the minimum building regulations standard (B Regs). This represents a subset of the dwellings being monitored as part of a study of energy consumption and Indoor Environmental Quality (IEQ) of houses on the island of Ireland (see figure 1).

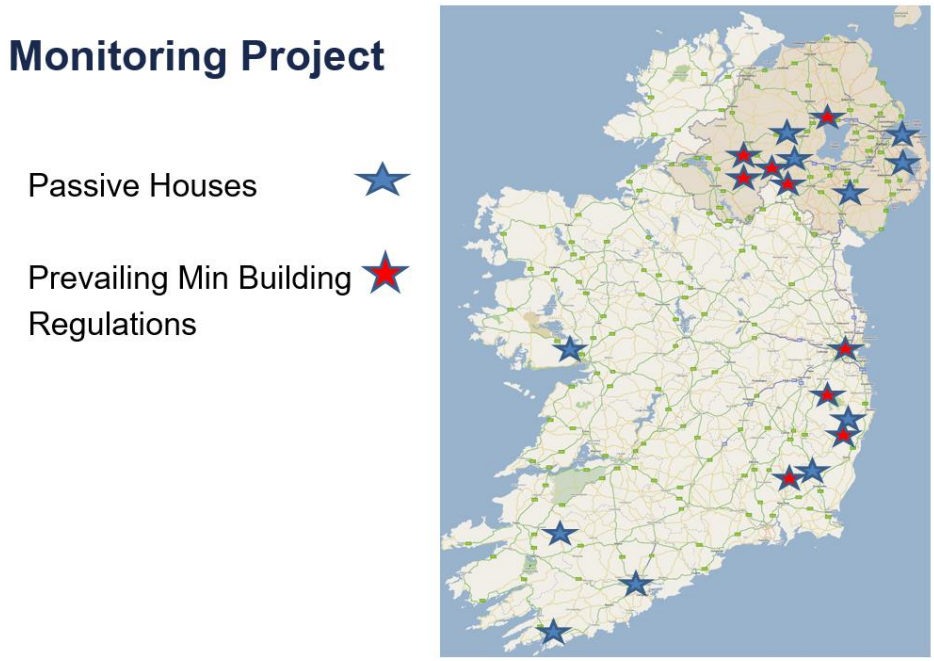

Figure 1 Locations of monitored passive houses and Building Regulations Houses

Installation of monitoring equipment in the living rooms and master bedrooms commenced in May 2016 for the nine Northern Ireland houses depicted in Table 1 and data is presented here for the period to March 2017. An analysis has been carried out to determine the performance of the passive houses (PH) compared with those complying with the minimum building regulations (B Regs) over the summer and winter period and this paper examines the performance of the Northern Ireland houses over the months of June, July and August 2016. While this report provides valuable insight into the performance of the house, the strength of the monitoring exercise being carried out by the Ulster University will be further enhanced by analysing the relative performance of the house compared with the other building regulations houses and passive houses being monitored at the same time, both in the Republic of Ireland and in Northern Ireland. This is the subject of a future paper.

Table 1 Overview of the Monitored Houses

House	Building Type	Construction	Constructed	Size {m^2}
PH 1	2 storey Hse, Detached	TF	2014	158
PH 2	Bungalow, Detached	TF	2013	220
PH 3	Bungalow, Detached	TF	2011	145
PH 4	Detached	TF	2016	247
PH 5	Under construction	n/a	2017	n/a
BRegs 1	2 storey Hse, Detached	Block	2010	329
BRegs 2	2 story hose, Detached	TF	2014	294
BRegs 3	2 Storey, Detached	Block	2013	230
BRegs 4	2 Storey, Detached	block	2016	210
BRegs 5	2 storey Hse, Detached	Block	2015	246

The following metrics are being gathered at five-minute intervals for the nine houses currently being monitored:

a. occupancy profile
b. indoor air temperature
c. indoor relative humidity
d. indoor carbon dioxide concentrations
e. outdoor temperature
f. outdoor relative humidity
g. wind speed
h. barometric pressure
i. energy consumption

The monitoring unit is a commercially available unit with the following specification:

Temperature (indoor): Ranges from: 0°C to 50°C. Accuracy: ± 0.3°C
Temperature (outdoor): Ranges from: -40°C to 65°C. Accuracy: ± 0.3°C
Humidity (indoor and outdoor): Ranges from: 0 to 100%. Accuracy: ± 3%
CO_2 meter (indoor): Ranges from: 0 to 5000 ppm. Accuracy: ± 50 ppm or ± 5%
Sound meter: Ranges from: 35 dB to 120 dB

Calibration tests have been carried out on the devices and it has been found that some individual units unit did not perform to the stated specification with respect to carbon dioxide concentrations, and also relative humidity. It was found that the RH of a number of the units exhibited an offset (of up to 10%, i.e. instead of reading the correct 70%, the unit records and indicated 80%). For this reason the RH is not discussed in detail in this report. The unit uses an optical CO_2 sensor and automatically re-calibrates at fixed intervals. This calibration is carried out assuming that the minimum CO_2 level reaches 400 ppm. Wide bands for carbon dioxide concentrations have been used to allow for any inaccuracies in CO_2 measurements and follow-on measurements are planned with laboratory grade carbon dioxide sensors. All units have been found to perform within specifications regarding temperature.

Thresholds have been established for the key metrics being monitored and the percentage of time individual metrics exceed the thresholds are considered. Passive Houses are designed to have a uniform set temperature of 20°C throughout. A temperature threshold has therefore been set at 20°C. Thresholds have been defined to reflect the set temperatures in SAP at 21°C for the living room and 18°C for the other parts of the dwelling.

A set temperature of 24°C is required in SAP in the case of air-conditioned buildings, and the final threshold temperature of 25°C reflects the temperature that passive houses are allowed to exceed for no more than 10% of the time.

Results

Despite the small sample size of four passive houses and five building regulations houses, some clear trends are emerging in relation to the interior temperatures experienced in the dwellings. It is noted that summer temperature readings are not available in B Regs 4 and PH 5 and that limited readings are available in PH 5. An analysis has been carried out of the

prevailing weather over the monitoring period, and it is noted that the summer of 2016 experienced similar temperatures to 2014 but higher temperatures than 2015 (by 1.1°C on average), but 30% less sunshine than the previous two years.

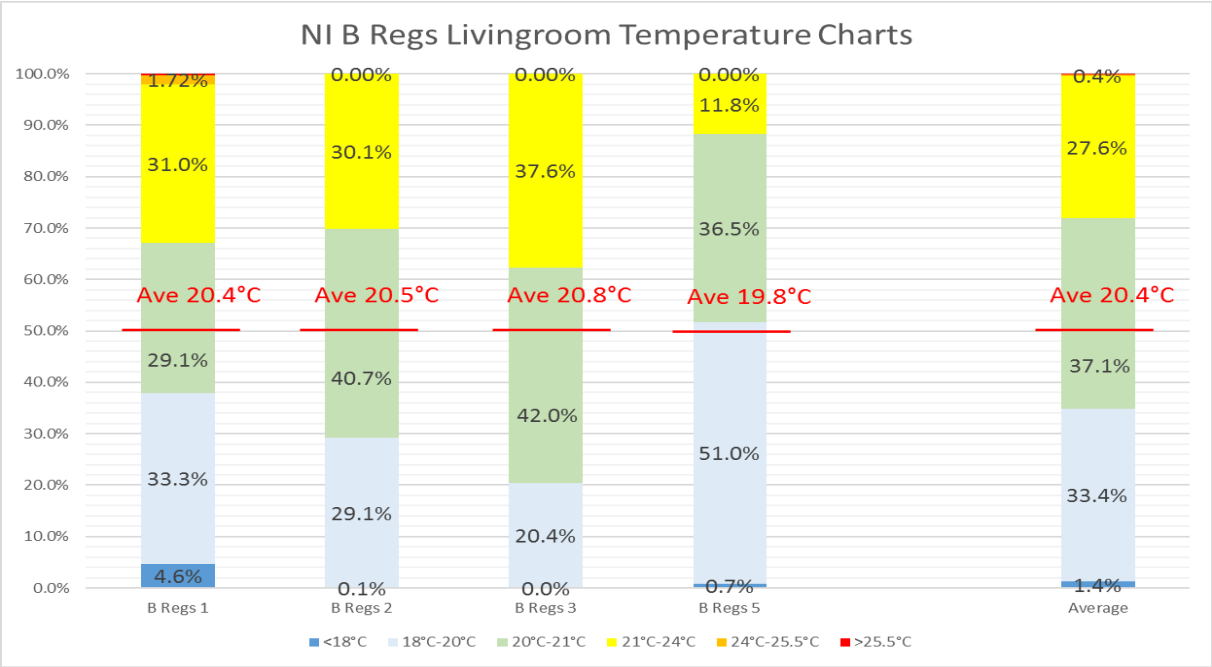

Figure 2 Average building regulations living room temps June, July, August 2016

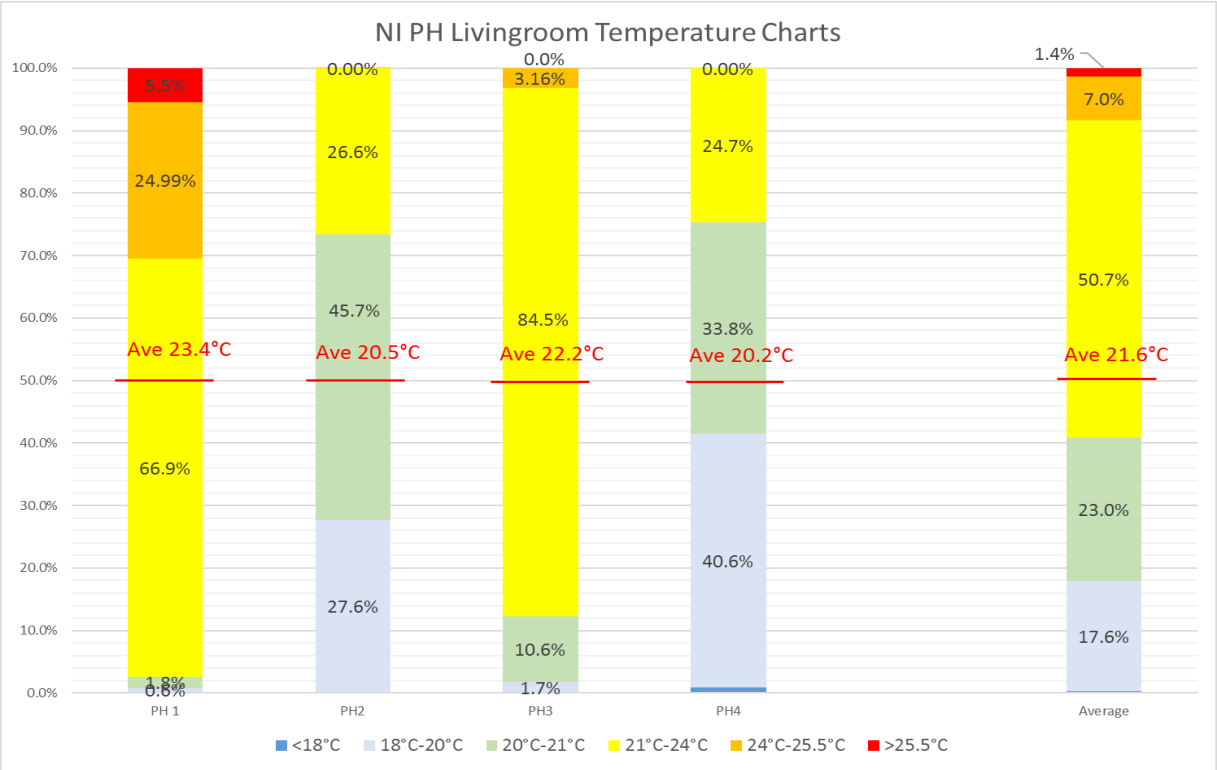

Figure 3 Chart of the NI Passive House living room temps, June July and August 2016

Figures 2, 3, 4 and 5 give the proportion of time that temperatures where experienced in the building regulations and passive houses both individually and as groups over the period

broken down into the distinct temperature bands previously defined in addition to the average temperatures.

Living room temperatures

Figures 2 and 3 refer to the living room temperatures. The average temperature in the group of building regulations houses is 20.4°C and that in the Passive House group is 21.6°C. Thus the average summer temperature in the Passive Houses is 1.2°C above that in the buildings complying with the minimum building regulations.

In addition, the living room temperature in the houses complying with the minimum building regulations are at or above the building regulations set temperature of 21°C for 28% of the time, while the average Passive House temperature meets or exceeds the set temperature of 21°C more than twice as frequently at 59% of the time.

Considering the set temperature for passive houses (20°C), the Passive House living rooms on average are seen to meet or exceed this threshold for 82% of the time, while the building regulations houses meet or exceed the temperature threshold for 65% of the time.

Regarding overheating, the average of the building regulations house living room temperatures do not exceed the threshold of 24°C, while the Passive House exceeds the threshold for 8.4% of the time, and exceeds the Passive House threshold of 26°C for 1.4% of the time. While these figures are well within the limit of 26°C for 10% of the year specified by the Passive House Institute the living rooms of the Passive Houses are seen on average to have significantly higher temperatures during the summer period than the houses merely complying with the minimum building regulations.

Considering the individual houses, PH 1 is seen to exhibit the highest temperatures, with temperatures exceeding 25.5°C for 5.5% of the time. A retractable awning was installed over the southerly fenestration in September 2016, to reduce summer overheating.

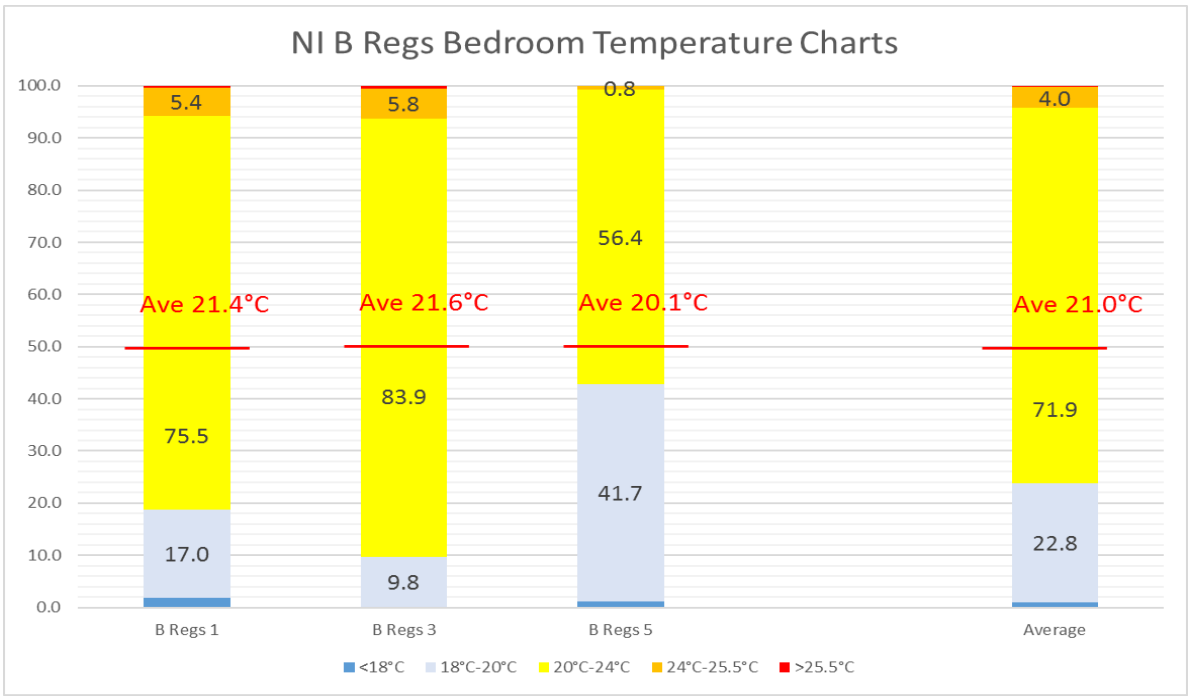

Figure 4 Chart giving the building regulations bedroom temps June, July, August 2016

Bedroom temperatures

Considering figures 4 and 5, it is seen that the trend of higher average temperatures continues in the passive house bedrooms, with the average temperature being 1.5°C higher in the passive houses (22.5°C compared with 21°C). During the summer period the temperature of the bedrooms in the passive houses and houses complying with the minimum building regulations consistently exceed the set temperature of 18°C required by the building regulations. Considering the Passive House standard set temperature of 20°C, the average temperature meets or exceeds this 95% of the time in passive houses and 76% of the time in houses complying with the minimum building regulations.

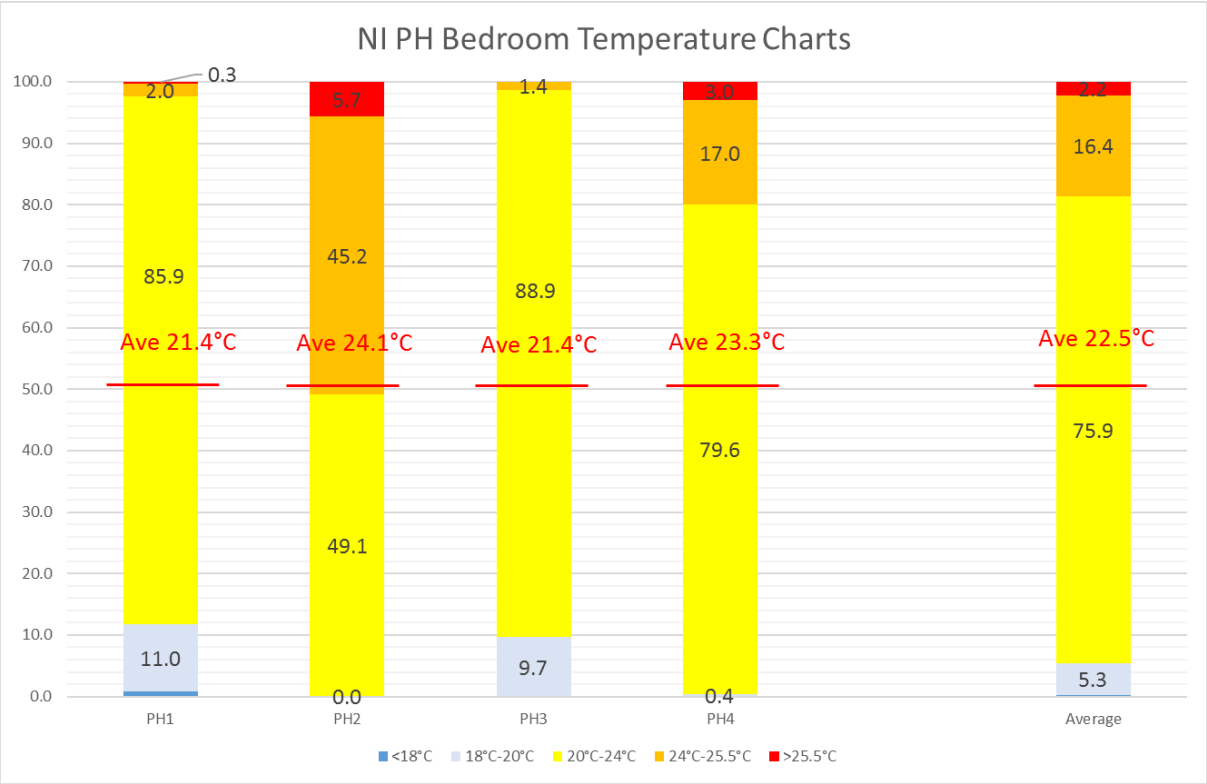

Figure 5 Chart giving the Passive House bedroom temperatures for June, July, August 2016

The temperatures in the Passive House bedrooms exceed the threshold of 24°C 18% of the time, and exceed the threshold of 26°C for 2.2% of the time. This compares with the building regulations bedrooms which exceeding the 24°C threshold only 4% of the time. Some passive houses are thus seen to record considerably higher temperatures than building regulations houses, whilst still operating within the Passive House maximum temperature limit of 26°C. It is noted that B Reg 1 and 2 had higher bedroom temperatures than PH 1 and 3, whilst experiencing slightly higher or similar average temperatures.

PH 2 is seen to exhibit the highest bedroom temperatures. The master bedroom is located on the second floor and opens onto a double height gallery which is directly over the living room. This is seen to contribute significantly to the high temperatures in the bedroom.

Qualitative assessment

In addition to the quantitative assessment reported above, the house owners were interviewed to assess their perception of Indoor Environmental Quality, along with a number of other questions in relation to their use of the property, overall satisfaction with the dwelling, costs and also the general suitability of the passive house standard for more

widespread deployment. This information will be presented as part of another paper. Table 2 looks specifically at Indoor Environmental Quality aspect and shows the level of occupant satisfaction based on perceived overheating, stuffiness, dry throat and noise of the mechanical heat recovery and ventilation system, in addition to overall IEQ satisfaction. Scores are rated on a scale of one (best) to 7 (worst).

Table 2 Occupants Satisfaction Levels

House	Overall IEQ Satisfaction	Overheating (Summer)	Stuffy (Winter)	Stuffy (Summer)	Dry Throat?	MVHR Noise
PH 1	1	3	1	3	1	1
PH 2	2	5	1	5	1	1
PH 3	1	2	3	2	1	1
PH 4	2	1	1	2	1	1
B Regs 1	1	2	2	2	1	1
B Regs 2	2	4	2	4	1	n/a

All owners reported some level of lack of satisfaction with high summer temperatures or summer stuffiness. The highest perceived overheating occurred in PH 2, with the owner reporting significant dissatisfaction during the summer with overheating, and a sense of stuffiness. This predominantly related to the night-time bedroom temperatures, which recorded the highest levels of the four passive houses studied, related to the location of the bedroom over the double height living room. In addition, the owner of PH 1 reported summer overheating in relation to bedroom temperatures.

The owner of B Regs 4 also reported significant dissatisfaction with overheating during the summer.

The owner of PH 3 reported more overheating and stuffiness during the winter period with the summer due to issues related to regulating the stove output, and the sometimes large number of visitors. She reported that the temperature was regulated by opening the doors to other rooms.

It is noteworthy that the building regulations house owners also reported summer overheating.

Corbon Dioxide Concentrations

In addition to the findings of higher temperatures in the passive houses, the passive houses were also seen to exhibit more uniform average concentrations of carbon dioxide (619 ppm for the living rooms and 616 ppm for the bedrooms) compared with the houses complying with the minimum building regulations (514 ppm in the living rooms and 820 ppm in the bedroom).

Conclusions

Monitoring has been carried out of four NI passive houses and four “standard” houses (built to the minimum building regulations) over the months of June July and August 2016. Both quantitative and qualitative analysis has been carried out to determine the performance of the two groups of houses.

A key finding is that differences are emerging in terms of the interior temperatures with the group of Passive Houses recording on average a 1.6°C higher temperature in the

living rooms and a 1.4°C higher temperature in the bedrooms compared with the building regulations reference houses.

On a quantitative basis neither the houses complying with the minimum building regulations nor the Passive House standard are seen to exhibit significant overheating. The passive houses are seen to experience more frequent breaches of the stipulated Passive House threshold of 26°C. All the passive houses complied with the requirement of not exceeding the 26°C threshold for more than 10% of the time. Despite operating within specifications, the majority of owners of the building regulations houses and passive houses perceived some level of overheating during the summer, and reported difficulty in regulating the temperature by opening the windows given the occasionally high outdoor night-time temperatures.

Acknowledgements

The authors wish to acknowledge the support of the Interdisciplinary Centre for Storage, Transformation and Upgrading of Thermal Energy (i-STUTE) under EP/K011847/1 for this research. In addition, sincere thanks is offered to the participants of the study.

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